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The Feral Buffalo Gourd, *Cucurbita foetidissima*

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The feral xerophytic Buffalo gourd, *Cucurbita foetidissima* HBK., has evolved in the semiarid regions of western North America and is well adapted to desert environments. It has abundant yields of seeds rich in oil and protein and abundant carbohydrate reserves in the form of starch in the large storage roots. Thus, this wild perennial has the potential of being a crop adapted to arid to semiarid lands, producing additional food critically needed to feed the world population.

DISTRIBUTION

The Buffalo gourd, like all species of *Cucurbita* is indigenous to the Americas, its progenitor presumably evolving from southern Mexico. Its present range (Fig. 1) extends from Guanajuato in central Mexico northward to the South Dakota border in the United States, a distance of about 2700 kilometers. Its general range and relative stand intensity is indicated in Figure 1. Its eastern advance into Missouri and Illinois is probably due to the activities of man as it is found mainly along railroads and highways. It is also likely that the stand in southern California was also established by man from seed (or fruit) which were carried across the Colorado River basin to the coastal mountain areas.

TAXONOMY

Cucurbita foetidissima HBK. was first described in 1817 and was later mistakenly named *Cucumis perennis* by James (1820), who found it growing from "arid and sandy wastes, along the base of the Rocky Mountains, from the confluence of the Arkansas, and Boiling Spring Fork, to the sources of the Red River" (Bailey, 1943). Asa Gray transferred it in 1852 as *Cucurbita perennis*, and under this name it remained until 1881 when Cogniaux brought up the name *Cucurbita foetidissima* of Humbolt, Bonpland and Kunth, having seen the Bonpland specimen in Paris (Bailey, 1943).

It is known by several common names such as Fetid gourd, Missouri gourd, Calabazilla and Chili Coyote. Just when the common name, Buffalo gourd, was coined is obscure. Stevens in 1948 called it Buffalo gourd in *Kansas Wild Flowers*. The term Buffalo gourd is currently in common usage.

PLANT MORPHOLOGY

Cucurbita foetidissima is perennial by virtue of the exceedingly large fleshy storage root it produces. Dittmer and Talley (1964) described a single root that weighed 72 kg for the central tap root alone. The uppermost lateral, which was dug out for a distance of 305 cm, weighed an additional 9 kg. Dittmer and Talley (1964) further described a *C. foetidissima* plant:

> Some idea of the prodigious vegetable growth of which *C. foetidissima* is capable is shown by the number of stems and shoots arising from the large tap root described here. Growing from the broad apex of this root, which had a maximum circumference of 4.7 ft. (143 cm), were 60 short, vertical, perennial stems which produced a total of 360 annual shoots. These shoots spread out on all sides of the central crown covering an area of 40 ft. (12.2 m) in diameter. The average length of each shoot was 20 ft. (6.1 m) and many of these gave rise to secondary branches. If only the number of primary shoots were considered, with their average length of 20 ft. (6.1 m), this plant would have a vine with a linear dimension of 7,200 ft. (220 m), all developed in a five month growing season. Counts were made of the number of leaves on 100 shoots, and the total number for this plant was calculated to be 15,720. Although this number seems high, we found that the leaves arise individ-

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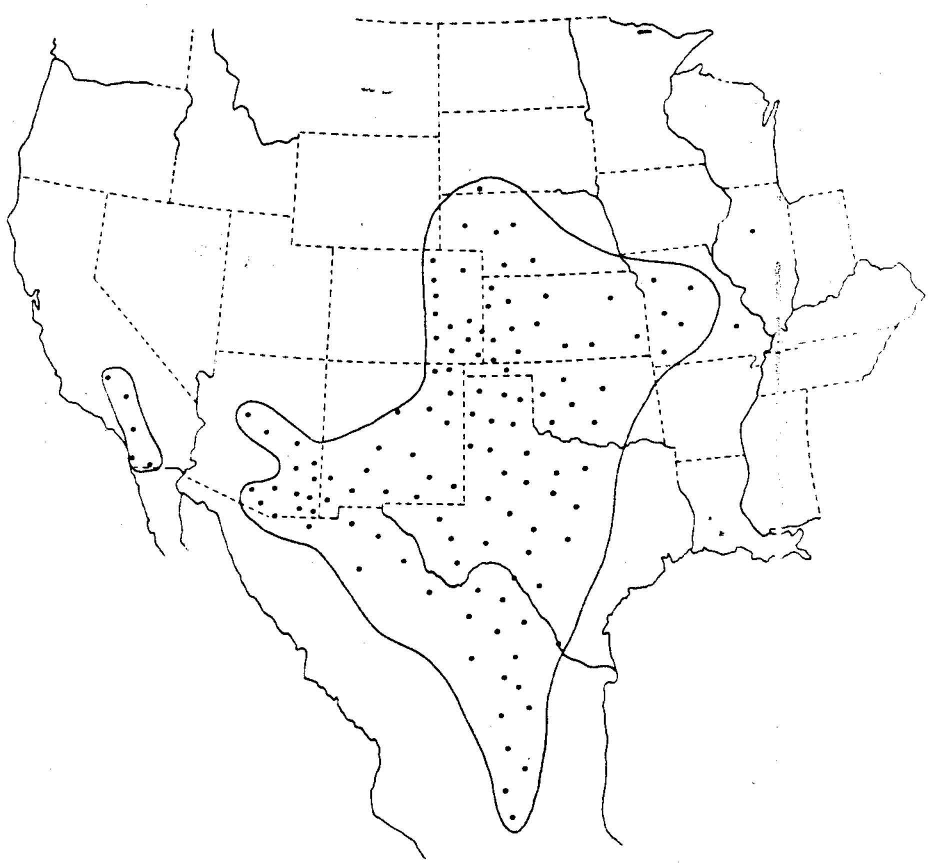

FIG. 1. A schematic diagram indicating the present natural range of *Cucurbita foetidissima* in North America.

ually on the stems with a spacing of 4–6 inches (10–15 cm) between the nodes. If we calculate the number of leaves based on 7,200 linear ft., we again come close to the 15,000 figure.

One half of the root from a four-year-old plant grown under cultivation in Lebanon is shown in Figure 2. The portion of the root shown in Figure 2 had a fresh weight of 45 kg, a length of 2.5 m and a crown diameter of 30 cm.

Leaves of *C. foetidissima* are typically entire and heart shaped with a 10–13 cm base and 20–25 cm length. The photosynthetic capability of these plants must be tremendous.

The flowers are borne singly at the nodes of the vines after a given amount of annual vegetative growth has taken place. Most observed under wild conditions are monoecious with the early flowers being male as well as the most abundant flowers being male. However, Curtis (1974) has isolated a genetic mutant that causes the male flowers to abort when approximately 2 mm long (fully developed male flowers are 10–12 cm long) and to produce more female flowers than the monoecious plants. In 1973 Curtis observed a mean of 272 fruit per plant for the 10 best mutant plants and a mean of 209 fruit per plant for the six highest yielding monoecious plants. The plants were in their third fruiting season and spaced 3 m × 3 m.

Cross pollination between flowers, even though they may be on the same plant, is necessary for fruit and seed development. This is accomplished mainly by the squash and gourd bees, *Peponapis* and *Xenoglossa* throughout its natural range of habitation (Hurd, Linsley and Whitaker 1971). The size of the fruit is known to vary, probably due to seasonal growth fluctuations and competition. Ba-Amer and Bemis (1968) collected open pollinated fruit from a homogeneous population of plants. The mean fruit weight was 119.6 g with a mean number of seed per fruit of 292. Three years later Costa and Bemis (1972) col-

FIG. 2. Dr. Curtis stands beside the excavated root (one half of the entire root system) of a four-year-old plant grown under cultivation in Lebanon.

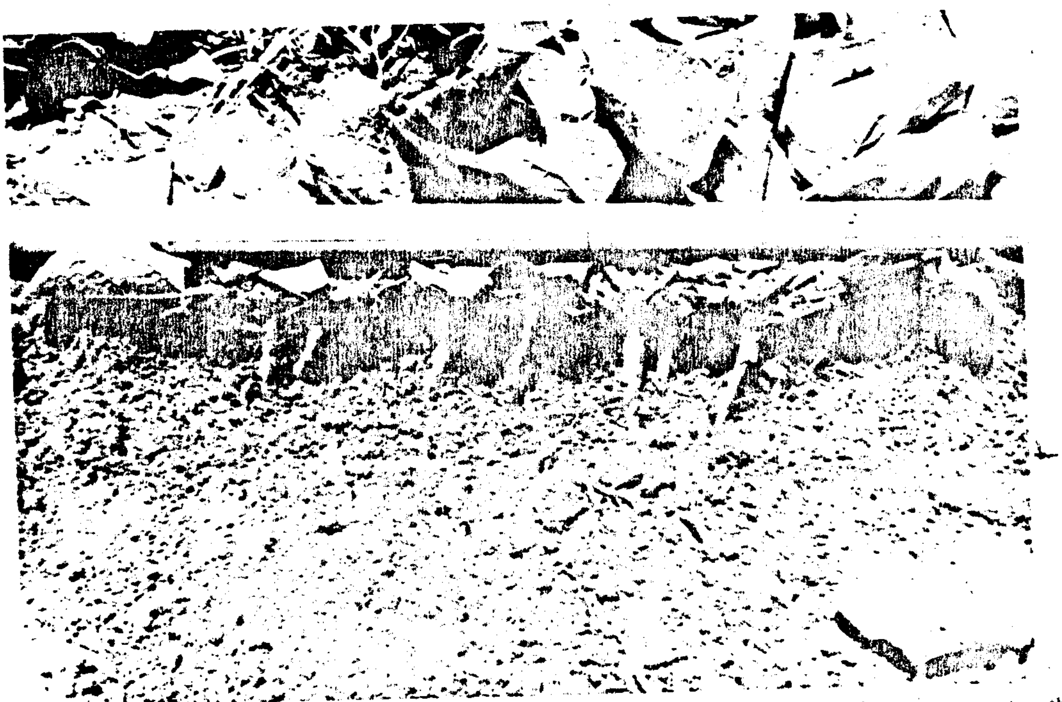

FIG. 3. Adventitious roots developing at the nodes of *C. foetidissima* vines when kept in contact with moist soil.

lected open pollinated fruit from the same plant population that had a mean of 151.8 g per fruit and a mean of 315 seed per fruit. The seeds weigh about 4 g per 100 and the seed coat accounts for about 30% of the seed weight (Hensarling, Jacks and Booth, 1973). The remainder of the seed, or 70%, is the oil- and protein-rich embryo that constitutes, in addition to its root reserves, that portion of the developed plant to be utilized as an agricultural crop.

MODE OF REPRODUCTION

Cucurbita foetidissima is a prolific producer of fruit and seed. As the fruit matures it abscisses from the vine and dries to a very thin fruit wall. At this point, seed produced by wild colonies of plants is extremely susceptible to predators such as rodents, birds and other seed-eating animals. Most observers of this plant share the opinion that its asexual mode of reproduction is probably the major method of dense colony formation of plants in areas of summer rainfall. Every node of the runner has the potential to develop an adventitious root if the moisture content of the soil or sand surface is sufficient and coincides with an appropriate physiological stage of development of a given node. Figure 3 shows the formation of adventitious roots induced by keeping nodes of the vine in contact with moist soil. If these nodal root initials are not kept moist until they develop into roots, they cease to develop and cannot be induced to continue growth once they have become dry. In this manner large homogeneous colonies are developed and, coupled with the perennial nature of the root system, continue to expand in size.

Under domestication, the Buffalo gourd could probably be successfully established, whether directly from seed, indirectly by transplanting seedlings, or by transplanting adventitious roots.

INTERSPECIFIC RELATIONSHIPS

A numerical taxonomic study of *Cucurbita* relationships (Bemis et al., 1970) has shown that *C. foetidissima* is not phenotypically similar to any other species or species group that were studied. Bemis and Whitaker (1969) describe four restricted xerophytic species, *C. cylindrata* Bailey, *C. cordata* Wats., *C. palmata* Wats., and *C. digitata* Gray. Although a fifth species, the wide ranging and variable *C. foetidissima* HBK., is truly xerophytic, it is only distantly related to the four above mentioned restricted species.

Many attempts have been made to hybridize the Buffalo gourd with other *Cucurbita* species and the only reported success was using it as a pollen parent with *Cucurbita moschata*, a domesticated species (Grebenščikov, 1956; Bemis and Nelson, 1963). In both cases the underdeveloped embryos had to be cultured and the hybrid, although vegetatively vigorous was completely sterile. Bemis (1970) successfully produced the amphidiploids of the hybrid and restored female fertility. The diploid hybrid at metaphase I configuration of meiosis contained from three to five loosely associated bivalents and 30 to 34 univalents ($n = 20$). The amphidiploid contained 40 bivalents at metaphase I. However, the particular *C. moschata* cultivar used in the initial cross contained a genetic factor which when combined with the *C. foetidissima* genome resulted in genetic male sterility. Other *C. moschata* cultivars which do not contain this incompatibility factor have been found and another attempt at producing fertile amphidiploids has been initiated.

GENETIC VARIATION

If, as suggested, the primary mode of reproduction is asexual, then one would not expect to observe much evidence of genetic variation, particularly within a colony that would essentially represent a clonal line. However, among colonies, especially those separated by great distances, one would expect to find variation. Bailey (1943) states, "This plant is so variable in leafage that one may wonder whether more than a single species is involved."

Curtis (1974) in his nursery in Lebanon, where he had a population of 730 plants from a rather limited number of crosses and selfs all originating from a common seed source, has observed and described seven unique plant types. In 1972 Dr. Curtis had oil and protein analysis made for 50 selected plants. The oil content varied from 25.6 to 42.8 percent and protein from 22.2 to 35.1. It is unknown if these differences are significant, but they are suggestive that genetic differences do exist for oil and protein content and can be selected to improve the crop.

COMPOSITION OF THE SEED

The economic importance of the oil and protein in Buffalo gourd seed is especially vital now during a protein and oil shortage in much of the world. This shortage, especially the protein, is critical in both human and animal nutrition, and encompasses the world from Central and South America through Africa to the Far East. In order to bring about a balance between population and the food supply, it is necessary to develop new sources of protein- and oil-rich seeds.

Average values for crude protein and crude oil in Buffalo gourd as analyzed by three different laboratories were approximately 32 and 30 percent for the protein and oil, respectively (Table I). A large variation in individual values was revealed when 50 different individual plant sources were analyzed (Curtis, 1972).

OIL CONTENT

Linoleic acid, a polyunsaturated fatty acid, comprises 60 percent of the oil derived from the Buffalo gourd seed. This fatty acid composition indicates that *Cucurbita* seeds are valuable sources of edible oil. Linoleic acid is the essential fatty acid required by both humans and animals in given daily amounts as specified by species requirements.

The fatty acid composition of Buffalo gourd oil is quite variable as shown by data from four different laboratories (Table II). The values of Shahani et al. (1951) and those of Weber (1972) are approximately the same, while the fatty acid values from Bemis et al. (1967) and Jacks et al. (1972) are different from each other and from the above two laboratories. Thus, it appears that seeds from different plants can vary in fatty acid composition by sizeable amounts. The essential linoleic acid concentration ranges from 38.0% to 65.3% for Buffalo gourd seed.

Another nutritional criterion of oils is their ratio of unsaturated to saturated fatty acids. In Table II, a range of 2.10 to 7.60 is listed for the four different laboratories. A high ratio

TABLE I

Cucurbita foetidissima Whole Seed Quality Expressed as a Percent of Seed Weight

Source	Curtis (1946)	Shahani et al. (1951)	Berry et al. (1976)	Weber et al. (1969)
Protein	34.2	31.7	32.9	32.3
Oil	33.9	24.3	33.0	30.4
Fiber	17.4	26.5	15.1	----
Ash	4.8	4.8	3.1	----

TABLE II

Composition of *Cucurbita foetidissima* Oil

Investigations	14:0[1] Myristic %	16:0 Palmitic %	18:0 Stearic %	18:1 Oleic %	18:2 Linoleic %	18:3 Linolenic %	Unsaturated[2] saturated
Weber (1972)	0.2	9.3	4.2	23.1	61.0	1.[illegible]	4.45
Bemis et al. (1967)	--	11.0	1.0	50.0	38.0	--	3.17
Jacks, et al. (1972)	--	14.2	8.4	28.5	47.3	--	2.10
Shahani, et al. (1951)	0.2	6.1	2.2	23.0	65.3	T	7.68

[1] Ratio of total carbon atoms of carbon - carbon double bonds.

[2] The ratio of unsaturated to saturated fatty acids.

TABLE III

Composition of Decorticated and Fat Extracted *Cucurbita foetidissima* Meal

Investigators	Crude protein %	Crude fat %	Crude fiber %	Moisture %	Ash %
Berry et al. (1976)	75.0	1.0	9.5	4.1	7.6
Shahani et al. (1951)[1/]	42.1	0.4	35.5	8.6	8.0
Bolley et al. (1950)	60.9	--	--	--	--
Hensarling et al. (1973)	62.5	--	--	--	--

1/. Seed was not decorticated.

TABLE IV

***Cucurbita foetidissima* Protein Quality Expressed as Percent of Protein**

Amino Acids	Sources of Data: Lyman et al. (1956) Whole Seed	Weber et al. (1969) Whole Seed	Weber et al. (1977) Whole Seed	Hensarling et al. (1973) Globulin
	(%)	(%)	(%)	(%)
Lysine	3.3	4.0	4.5	3.3
Histidine	1.9	2.1	2.2	2.5
Arginine	14.2	13.0	13.0	16.8
Threonine	2.6	1.5	2.0	3.5
Valine	4.8	4.0	3.8	5.0
Methionine	1.9	1.4	2.1	2.5
Isoleucine	4.4	3.2	3.3	4.1
Leucine	6.6	4.6	5.4	7.8
Tyrosine	---	3.9	4.0	3.9
Phenylalanine	4.6	---	3.6	5.9
Aspartic Acid	---	---	9.5	10.9
Serine	---	---	4.1	5.9
Glutamic Acid	---	---	17.2	21.5
Proline	---	---	2.7	4.5
Glycine	---	---	8.1	4.8
Alanine	---	---	3.3	5.0
Cystine	---	---	0.9	0.7
Tryptophan	1.6	---	1.0	0.6

is desirable if the primary unsaturated fatty acid is linoleic. Two common oils used domestically are corn and soybean, which have ratios of 3.18 and 3.40 respectively.

A diverse genetic material base is essential in the selection of parental stock. The large variation in both percent crude oil of the seed and the fatty acid pattern itself is desirable for selection of plants for the establishment of a Buffalo gourd plantation.

PROTEIN CONTENT

Whole Buffalo gourd seeds contain approximately 31 percent crude protein. This protein level is higher than that of other oil seeds with the exception of soybeans. When oil and/or fiber of the seed are removed, the protein level increases to a relatively high level (Table III).

Material that has been both decorticated and fat-extracted has a range of crude protein from 60.8% to 71.9%, respectively. A meal analyzed by Berry et al. (1976) had 75% protein, 9.5% fiber and an ash content of 7.6%, which is well within the range of other oil seed sources (Table III). While both values reported by the other two laboratories for decorticated and fat-extracted material are lower than the 75% values found by Berry et al. (1976), no fat, fiber, or ash values are given, so comparison is difficult. It is not clear whether the differences are due to seed concentrations of crude protein or to fat extraction or fiber removal.

Shahani et al. (1951) found 42% crude protein in meal that was fat-extracted but not decorticated. The high fiber level of 35.5% confirms the presence of the seed coat in the meal.

Bolley et al. (1950) stated that there were differences in the physical properties between Buffalo gourd seed protein and other seed proteins prepared by the same procedure. Moreover, they considered the *Cucurbita* proteins to have industrial potential for such products as water paints, paper coating, adhesives and textile sizing. Further purification of crude

TABLE V

Effect of Dietary Protein Source in Rat and Mouse Feeding Trials

Dietary source of protein	Protein Efficiency Ratio (PER) Rat[1/] (10%)	Mouse[2/] (7%)
Casein	3.56	---
Whole egg	---	3.40
Buffalo gourd (without seed coat)	2.36	---
Buffalo gourd whole seed	---	2.79
Buffalo gourd whole seed (Autoclaved)	---	2.24

1/. Jacks et al. 1972

2./ Weber. 1969 and 1972.

Buffalo gourd protein resulted in the isolation of a globulin that constitutes 80–95% of the total protein (Jacks et al., 1972). The high level of protein (75%) found by analyses of decorticated and fat-extracted Buffalo gourd meal suggests great potential for the meal as either a food or feed source.

To assess the protein quality of *C. foetidissima* seeds for food use, the amino acid composition of the meal was determined. Three separate laboratories analyzed either whole seed or isolated globulin for their amino acid composition. The concentration of essential amino acids varied among the four determinations. Hensarling et al. (1973) isolated a crystalline globulin in 38% yield from decorticated oil-free meal. It showed a somewhat different amino acid distribution than whole seed protein. Comparison with the whole seed protein reported by Lyman et al. (1956) and Weber et al. (1969, 1977) showed differences in certain essential amino acids, which may be due to variation between individual plant sources of seeds. The quality of the Buffalo gourd was evaluated by the methods of chemical score (Mitchell and Block, 1946) and protein score (FAO/WHO, 1973). The sulfur amino acids were first limiting, using either the chemical or protein score method.

A second means of testing protein quality involves the use of laboratory animals in feeding trials. Two species of animals were employed to test the protein quality of Buffalo gourd seed in separate studies, using the parameter of protein efficiency ratio (PER). Comparable results were found between the rat and mouse for PER values of *C. foetidissima* (Table V).

The decorticated Buffalo gourd seed when fed to rats had a PER value of 2.36 while the whole seed fed to mice had a PER of 2.79. These rat and mouse PER's indicate that the Buffalo gourd protein is comparable in quality to the other known oil seed meals.

STARCH IN THE ROOT

Laboratory studies (Berry et al., 1975) of the root of the Buffalo gourd have established that it contains an abundant quantity of starch. Roots of plants in their second year of growth were collected for study. After washing and trimming, they were disintegrated in dilute salt solution by means of a mechanical food blender. Subsequent operations of filtration, settling, washing and drying provided a homogeneous starch. The starch yield was 50–56 percent of the dry weight of the roots.

Confirmation of the identity of the isolated material as starch follows from its intense deep blue color reaction with iodine solution, its hydrolysis with dilute acid to yield only glucose as shown by paper chromatography, its X-ray diffraction pattern typical of starches, and its characteristic granular structure as revealed in photomicrographs. Other physical and chemical properties are under study.

Isolation in the manner described provided a starch which appears to be free of cucurbitacins, the extremely bitter glycosides present in the roots, leaves and fruit of this gourd.

SUMMARY

The feral species, *Cucurbita foetidissima*, the perennial Buffalo gourd, has the potential of becoming a cultivated food crop, producing seeds rich in edible oil and protein. It also produces an extensive storage root system rich in starch. It has evolved in the arid regions of North America and is adapted to growing on arid to semiarid lands, which constitute much of the world's land mass, lands now marginal for crop production.

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